The influence of the guiding magnetic field on the performance of a Smith–Purcell amplifier operating in the strong Compton regime

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In a Smith–Purcell amplifier, the guiding magnetic field couples the TE and TM modes. However, for an incident TM wave it is shown that the scattered TM waves can be determined with the induced TE waves neglected, the latter being treated within a first-order approximation. The response function of the amplifier for the TM waves is derived, and the dependence of its poles on the intensity of the guiding magnetic field is investigated. It is found that there are five poles, two of them complex, irrespective of the guiding field intensity and related to the "pure" slow-wave-structure poles; two other poles may be complex only if the cyclotron frequency is below a "cutoff" (determined explicitly) and resemble "gyrotron" poles. The cutoff is shown to be proportional to the shift (due to collective effects) in the radiation wave vector. The first pair of poles emerges from the longitudinal electronic oscillation, while the second pair corresponds to the transverse oscillation. The real pole into which the "gyrotronlike" poles degenerate is precisely the third pole, which occurs in slow-wave structures under strong magnetic fields. By a suitable choice of the magnetic field a 10% increase is obtainable in the gain of the amplifier; this optimal field is determined and shown, within the relevant range of parameters, to be linear with the device length.